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Influence of cultivar and growing season on quality properties of winter wheat (*Triticum aestivum* L.)

Veselinka ZECEVIC[1]*, Jelena BOSKOVIC[1], Desimir KNEZEVIC[2], Danica MICANOVIC[3] and Slobodan MILENKOVIC[1]

[1]Faculty of Biofarming, Megatrend University Belgrade, Marsala Tita 39, 24300 Backa Topola, Serbia.
[2]Faculty of Agriculture, University of Pristina, Kopaonicka bb., 38217 Lesak, Kosovo and Metohia, Serbia.
[3]Serbian Chamber of Commerce, Belgrade, Resavska 15, Serbia.

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Quality of nine winter wheat cultivars (Ana Morava, Aleksandra, Toplica, KG-56S, Kruna, Planeta, Takovcanka, Vizija and Studenica) was studied in this paper. Field experiment was conducted in three growing seasons (2005/06, 2006/07 and 2007/08) on the experimental field of Small Grains Research Centre of Kragujevac, Serbia. Zeleny sedimentation value, wet gluten content and rheological properties of flour and dough (water absorption, dough development time, dough stability time, and dough softness) were analyzed. There was a significant effect of year on the value of studied quality components of grain and flour. The investigated wheat cultivars had quality at first and second quality class. Farinograph properties have shown that flour of analyzed cultivars belonged to A_2 and B_1 quality groups. The results showed that the variety Ana Morava, Aleksandra, Toplica and KG-56S hade excellent grain and flour quality. Analysis of variance showed highly significant differences among cultivars, years and its interactions for investigated quality properties.

Key words: Wheat, cultivar-year interaction, quality, rheology.

INTRODUCTION

Breeding for improvement in bread-making quality of wheat is an important breeding goal. Research of technological quality of new wheat cultivars in different ecological conditions is important for determining the stability of cultivars for specific characteristics. The successful process of wheat breeding is based on the knowledge of characteristics of genotypes, environment and its interaction. The ideal cultivar for high grain yield or for any other desirable traits needs to express genetic potential with low value of variance in different environmental factors of growing.

Good baking quality has been one of the priorities in wheat breeding programes at Small Grains Research Centre Kragujevac. Adaptedness and productivity are however both complexly inherited traits and much affected by environment (Alard, 1997). The successful process of wheat breeding is based on the knowledge of quality characteristics of genotypes as well as interactions of genotypes and environments. The ideal cultivar for high technological quality and grain yield need to express genetic potential in different environmental factors of growing.

Understanding of the causes of genotypic × environment (G × E) interaction can be used to establish breeding objectives, identify ideal test conditions, and formulate recommendations for areas of optimal cultivar adaptation (Yan and Hunt, 2001). The presence of G × E interaction complicates selection of superior genotypes

*Corresponding author. E-mail: joca@kg.ac.rs. Tel: + 381 24 718 515.

Table 1. Monthly temperatures and monthly precipitation for the three growing seasons (2005-2008) and long-term period (1980-2006).

Month	Temperature (°C)				Precipitation (mm)			
	2005/06	2006/07	2007/08	1980-2006	2005/06	2006/07	2007/08	1980-2006
Oct	11.5	13.3	10.8	12.5	49.0	16.7	92.8	52.1
Nov	5.6	7.6	4.5	6.8	54.8	13.7	110.4	55.4
Dec	3.3	3.5	0.6	2.7	47.1	51.9	28.1	53.3
Jan	-1.7	6.1	2.5	4.3	27.9	45.3	36.6	35.4
Feb	1.5	6.3	4.5	5.4	38.1	32.1	13.0	43.2
Mar	5.6	9.1	8.1	8.6	116.1	62.9	53.2	56.3
Apr	12.7	12.1	12.6	12.4	86.3	3.6	30.1	67.8
May	16.4	18.2	17.3	17.8	29.6	118.4	13.1	51.8
Jun	19.7	22.8	21.8	22.3	84.8	25.3	65.7	68.3
$\bar{x}$ / $\sum$	8.3	11.0	9.2	10.3	533.7	369.9	443.0	483.6

and understanding of environmental and genotypic causes of significant G × E interaction is important at all stages of plant breeding (Dhungana et al., 2007).

There is inverse relationship between grain yield and protein content. Since bread making quality is influenced by both protein quantity and quality, breeders should apply breeding strategies to increase one without affecting the other to achieve specific wheat quality classes. The basic principles to quality improvement are understanding effects of G × E interactions on the expression of quality traits and understanding genetic control and diversity associated with quality traits (Abugalieva and Peña, 2010). The optimum ecological environment benefited from the development of grain and optimal ratio of quantitative amount of gliadin and glutenins, which influenced gluten quality (Lookhart et al., 2001).

Except that, gluten quality depends on the amount and ratio of HMW and LMW glutenins, gliadins, their structure, and on amino-acid content. Also, gluten of high quality depends on temperature and moisture conditions during maturation (Torbica et al., 2007; Knezevic et al., 2009; Zecevic et al., 2009). The interaction of environmental and genetic factors on wheat plants, have effect on grain quality as well as gluten quality (Jing et al., 2003). Several studies have generally shown that environment, genotype and G × E interactions are all significant factors contributing to different expression of quality (Mikhaylenko et al., 2000; Panozzo and Eagles, 2000; Preston et al., 2001; Zhang et al., 2004; Finlay et al., 2007; Williams et al., 2008).

The objective of this research was to study the effect of genotype and growing seasons on some technological properties in divergent winter wheat cultivars.

MATERIALS AND METHODS

Nine winter wheat cultivars (Ana Morava, Aleksandra, Toplica, KG-56S, Kruna, Planeta, Takovčanka, Vizija and Studenica) were grown during three growing seasons (2005/2006, 2006/2007 and 2007/2008) at experimental field of Small Grains Research Centre of Kragujevac Serbia (20°55'12"E, 44°01'12"N, 185 m asl).

The field experiment was set up on the soil which belongs to the smonitza (vertisol) type, with a relatively high clay content and the unfavorable physical properties. The content of humus in the surface layer of soil is medium (2.51%), and substitutional and total hydrolytic acidity are quite high (pH H_2O=5.16 and in KCl = 4.91). The soil is well provided with total nitrogen (0.16% N) and easily available potassium (29.2 mg/100 g soil K_2O), and poor in available phosphorus (17.6 mg/100 g soil P_2O_5).

The field experiment was set up as a randomized block design with three replications. Experiment was carried out by the standard technology of scientific farming production of wheat. Wheat cultivars were cultivated in rotation with field pea. Sowing was carried out at optimal time (from October 10 to 15) with 600 germinated seeds per m², as common practice in this region. The size of basic plot was 5.0 m².

Influence of genetic and agro-ecological conditions on quality properties of wheat grains, flour and dough (sedimentation value, wet gluten content, water absorption, dough development time, dough stability time, and dough softness) were investigated. Based on the results of farinogram determined the quality number and quality group of flour. In Serbian method, the quality number represents the area enclosed by line passing through the centre of the farinograph curve and the central line which passes through the maximum of the curve (500±10 FU). According to the value of the area, wheat flours are classified into six quality classes: A_1 (0 to 1.4 cm^2), A_2 (1.5 to 5.5 cm^2), B_1 (5.6 to 12.1 cm^2), B_2 (12.2 to 17.6 cm^2), C_1 (17.7 to 27.4 cm^2) and C_2 (27.5 to 50 cm^2), according to Dapcevic-Hadnadjev et al. (2011).

Grain samples were milled using a Brabender Quadrumat Junior laboratory mill. The quality analysis of Zeleny sedimentation test and wet gluten content were done by ICC standard methods No. 116/1 and 106/2, respectively (1972, 1992). The rheological properties were determined by using Farinograph Brabender according to ICC standard method No. 115/1 (1972, 1992).

Data were subjected to analysis of variance (ANOVA) as randomized complete block design with two main factors (genotype and year) using MSTAT-C statistical software. The significant differences between the means were grouped according to least significant difference (LSD).

Climatic conditions during the experiment

Climatic conditions during the experiment and long-term period are shown in Table 1. Mean monthly air temperatures differed by years

Table 2. Mean values for sedimentation value (SV) and wet gluten content (WGC).

Cultivar	Year							
	2005/06		2006/07		2007/08		Average	
	SV (ml)	WGC (%)	SV (ml)	WGC (%)	SV (ml)	WGC (%)	SV (ml)	WGC (%)
Ana Morava (a)	32.7	33.58	35.0	29.70	46.33	34.13	38.0[afgi]	32,47[a]
Aleksandra (b)	42.7	36.29	42.7	34.27	47.7	35.50	44.3[bcd]	35.35[bd]
Toplica (c)	35.3	39.81	47.0	38.71	47.3	37.07	43.2[cdb]	38.53[c]
KG-56S (d)	37.3	36.29	45.3	34.27	45.0	35.50	42.6[dbc]	35.35[db]
Kruna (e)	32.7	32.89	38.0	28.71	39.7	27.85	36.8[eah]	29.82[e]
Planeta (f)	32.0	31.09	36.0	29.69	44.3	33.80	37.4[fa]	31.53[f]
Takovcanka (g)	34.0	27.87	39.7	28.87	45.3	28.70	39.7[gafi]	28.48[g]
Vizija (h)	33.0	34.77	35.3	28.80	35.3	28.16	34.6[he]	30.58[h]
Studenica (i)	36.3	34.67	38.7	33.68	45.0	34.33	40.0d[iga]	34.23[i]
Average	35.11	34.14	39.74	31.86	44.00	32.78	39.6	32.93

* Means followed by different letters are significantly different at 0.05 probability level. The combination of different letters in the same row means the group of cultivars which are not significantly different at the 0.05 probability level.

of research. The highest mean monthly temperature was in the 2006/07 growing season (11.0°C). In 2006/07, average temperature was higher than in other both years and long-term period. Mainly differences were in the winter period when plants were in hibernation that did not significantly influence on plant growing. Sums of precipitation were higher in 2005/06 growing season (533.7 mm) and 2007/08 (443.0 mm) than in 2006/07 (369.9 mm) investigated growing season. According to long-term period, precipitations in 2005/06 vegetative period were higher for 50.0 mm, while in 2006/07 and 2007/08 were lower for (113.7 and 40.6 mm, respectively). The largest differences in precipitation were in March 2006 and in May and November 2007 year.

RESULTS AND DISCUSSION

The sedimentation value is an indicator of gluten quality. Zeleny sedimentation value depends more on the qualitative variation of storage proteins than on their quantity and is mainly affected by the genotypic and environmental effects (Grausgruber et al., 2000). According to research conducted by Peighambardoust et al. (2011), Zeleny sedimentation showed significant correlation with loaf volume and bread height. The results for sedimentation values of investigated cultivars are shown in Table 2. This quality component differed between cultivars and investigated growing seasons. On average for all varieties, the value of sedimentation was about 40 ml. Average values of sedimentation have varied in the range of 34.6 ml (Vizija) to 44.3 ml (Aleksandra). The highest values for sedimentation were found for Aleksandra and Toplica varieties in 2007/08 growing season (47.7 and 47.3 ml, respectively) that indicated a very good quality of these cultivars. Looking at the years, the average sedimentation value was highest in growing season 2007/08 (44.0 ml) than in other two investigated years. This growing season had similar average temperatures and precipitation with long-term period. The distribution of rainfall during the grain filling was favorable, which had a positive effect on wheat quality. All tested cultivars had a sedimentation values on the level of the first quality class or at the level of varieties improvers, except varieties Vizija (34.6 ml) and Kruna (36.8 ml), which belonged to second quality class. Glutenin content had a positive genetic correlation with technological quality of flour, sedimentation volume, whereas gliadin had a negative correlation to the flour quality and rheological dough properties (Lookhart et al., 2001; Knezevic et al., 2005).

Wet gluten content and sedimentation value are important quality components which directly depend on grain protein content, especially on storage protein components. Gliadins and glutenins are the main components of storage proteins and have a positive influence on gluten quality (Metakovsky et al., 1991; Menkovska et al., 2002; Djukic et al., 2008). In the present work, wet gluten content in average for all years was highest in Toplica (38.53%) and lowest in Takovcanka (28.48%). Most of tested cultivars showed high level of wet gluten, being higher than 30% (Table 2). The average wet gluten content was higher than 30% in all years, and the highest value was found in the 2005/06 growing season (34.14%). Gluten, the main protein of wheat flour, consists of two main fractions known as glutenin and gliadin. It is considered that differences in bread-making quality of bread wheat cultivars are ascribed to protein, especially glutenin fraction (Knezevic et al., 2005). It is well known that wheat grown under high temperature and low moisture characterize strong gluten with less extensibility and the opposite conditions produce weak gluten and extensible dough. Genotypes with higher gluten strength have been characterized as bread improvers and these have shown higher contents of total glutenins as well as content of high-molecular-weight glutenin subunits (Horvat et al., 2009).

Analysis of variance showed highly significant differences among investigated genotypes (G), years (Y) and among their interactions (G × Y) for sedimentation value and wet

Table 3. Analysis of variance for sedimentation value (SV) and wet gluten content (WGC).

Source	DF	MS		F		LSD			
						0.05		0.01	
		SV	WGC	SV	WGC	SV	WGC	SV	WGC
Genotype (G)	8	95.67	92.25	21.91**	232.17**	2.271	0.685	3.305	0.997
Year (Y)	2	533.64	35.60	122.24**	89.60**	2.447	0.738	5.644	1.702
G x Y	16	21.78	8.77	4.99**	22.07**	3.617	1.091	4.983	1.503

** Significant at the 0.01 probability level according to F-test.

Table 4. Mean values for rheological properties of wheat flour and dough.

Cultivar		WA (%)	DDT (min)	DST (min)	DS (BU)	Quality number	Quality group
Ana Morava (a)		67.4^{a}	3.5^{a}	4.5^{a}	40^{a}	79.2	A_2
Aleksandra (b)		63.5^{b}	2.0^{bgi}	8.0^{b}	30^{b}	80.8	A_2
Toplica (c)		65.5^{cgi}	3.0^{c}	5.5^{c}	20^{c}	84.2	A_2
KG-56S (d)		62.8^{d}	2.5^{d}	6.5^{d}	50^{dhi}	83.7	A_2
Kruna (e)		64.6^{ef}	1.5^{ef}	1.0^{eh}	70^{e}	65.0	B_1
Planeta (f)		64.3^{fe}	1.5^{fe}	2.0^{fg}	65^{f}	66.4	B_1
Takovcanka (g)		65.9^{gci}	2.0^{gbi}	2.0^{gf}	60^{g}	58.5	B_1
Vizija (h)		61.8^{h}	1.0^{h}	1.0^{he}	50^{hdi}	59.0	B_1
Studenica (i)		65.5^{icg}	2.0^{ibg}	2.5^{i}	50^{idh}	65.2	B_1
	G	0.51	0.30	0.32	1.75		
LSD 0.05	Y	0.54	0.32	0.35	1.89		
	G × Y	0.80	0.48	0.52	2.79		

Water absorption (WA), Dough development time (DDT), Dough stability time (DST), Dough softness (DS), Brabender units (BU). * Means followed by different letters are significantly different at 0.05 probability level. The combination of different letters in the same row means the group of cultivars which are not significantly different at the 0.05 probability level.

gluten content (Table 3). The strongest individual influence for sedimentation value had year (F=122.24**), genotype (F=21.91**), but lowest interaction (F=4.99**). For wet gluten content, the strongest individual influence had genotype (F=232.17**), year (F=89.60**), but lowest interaction (F=22.07**) which is in agreement with previous results by Curic et al. (2009). Bread-making quality of wheat is affected by genetics, environmental conditions and crop management (Pepo et al., 2005; Horvat et al., 2006; Drezner et al., 2007). Environmental factors are always different in time and space and their changes are mostly the greatest. In previous investigations, sedimentation value and wet gluten content also significantly depended on environment, cultivar, year and their interactions (Knezevic et al., 2005; Svec et al., 2007; Zecevic et al., 2007; 2010; Mikulíková et al., 2009).

The results for rheological properties: water absorption (WA), dough development time (DDT), dough stability time (DST) and dough softness (DS) of investigated cultivars is shown in Table 4. Water absorption has been considered to be a function of starch damage, non-starch polysaccharide content and protein content (Mann et al., 2009). Absorption measures the amount of water that can be absorbed by a given quantity of flour. In bread making, it is usually preferable to have flour that can absorb a large amount of water. Optimum absorption represents the maximum amount of water, as a percent of the flour weight, that will produce a high yield of bread during the baking process. In previous investigation of correlations between rheological properties, strong correlation between dough stability time and farinograph absorption and protein content was established (Koppel and Ingver, 2010). In general, high water absorption means good baking performance. It is considered that high protein quantity provides both high water absorption and good baking performance (Bloksma, 1990; Basaran and Göçmen, 2003). The high molecular weight glutenin subunits play an important role in governing the functional properties of wheat dough (Peña et al., 2005; Torbica et al., 2007). Weak gluten flour has a lower water absorption and shorter stability time than strong gluten flour. Water absorption and dough stability time are in significant positive correlations with protein concentration and gluten content (Seleiman et al., 2011).

In this investigation, the water absorption varied in accordance with genotype and years (Table 4). The factors genotype and year affected WA significantly, but

G × E interactions were not significant. Average absorption value ranged from 61.8% (Vizija) to 67.4% (Ana Morava). Genotypes reacted differently on investigated growing season. The rheological properties were influenced by production years and cultivars. Farinograph properties have shown that wheat flour on average belonged to A_2 and B_1 quality group meaning that tested cultivars had high technological quality. Quality number varied from 58.5 (Takovcanka) to 84.2 (Toplica). Rheological properties of dough (dough development time, dough stability time and dough softness) were different and depending on cultivars and years. The factors genotype and year affected DDT and DST significantly, and G × Y interactions for these traits were also significant. Difference in the climatic conditions in different years remarkably affected DST, which is in accordance with previous research (Tian et al., 2007). Significant effects of genotype and year were observed for DS, but G × Y interactions for this trait were not significant. According to Campos et al. (1997), dough development is a function of many factors: composition, moisture content, degree of energy input, temperature, and flour quality.

Previous works showed that the quality number of the wheat flour dough was closely correlated with the strong gluten flour, which had high dough stability, high dough breakdown time, a high farinograph quality number, and low dough mixing tolerance index (Lei et al., 2008). In this work, the farinograph quality number was highly and positively correlated with dough breakdown time, dough stability, and dough development time, and highly negatively correlated with the mixing tolerance index. Environment affected significantly the most of chemical and rheological properties of flours extracted from both soft and hard wheat (Hazen and Ward, 1997; Mikhaylenko et al., 2000; Deng et al., 2007).

Contrasting growing season conditions affected significantly the sedimentation value, wet gluten content and flour water absorption. There was also a significant genotype effect shown by variability parameters (Peña et al., 2005; Horvat et al., 2009; Mann et al., 2009; Zecevic et al., 2009). This strong effect of the year on quality traits of wheat is in agreement with results of previous investigations (Johansson et al., 2004; Drezner et al., 2007; Williams et al., 2008; Hristov et al., 2010; Zecevic et al., 2010; Atanasova et al., 2010).

Conclusions

Quality properties of grain, flour and dough were affected by years, cultivar and their interactions. Growing season had significant effect on sedimentation value, wet gluten content and rheological properties. Significant differences among wheat cultivars according to analyzed quality parameters were established. This difference was based on genetic specificity of wheat cultivars according to expression of quality characteristics and cultivar reaction to environmental factors which were different in year of investigation. Also, quality properties are influenced by interaction of genotype and environment. The important role for quality have complex proteins (gliadin and glutenin) which is genetically determined and environmental factors (temperature and moisture) have influence to formation of quality values from milk stages of ripening to full maturity. Quality of investigated cultivars was high and belonged to A_2 and B_1 quality group. The highest quality had cultivars Ana Morava, Aleksandra, Toplica and KG-56S, which belonged to A_2 quality group.

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